The 2024 ROSENTHAL PRIZE
for Innovation and Inspiration
in Math Teaching

A Day in the Life of a Paleontologist

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Grade 6

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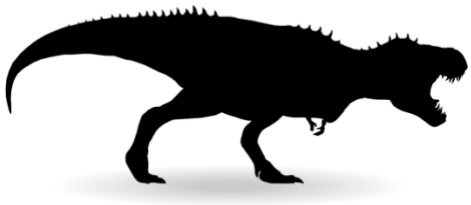
Introduction



This movement-based activity builds a bridge between mathematics and science as students explore what it is like to be a paleontologist. Students learn about a classroom dino by studying trackways and taking measurements of stride length and foot length, just as paleontologists do! During the activity, students measure and analyze their own hip height to foot length ratios, estimate their own stride length, analyze class data, and connect their data to actual paleontologists' research and findings. The activity unifies asking statistical questions and analyzing data by leveraging boxplots and ratios. The two-day activity culminates in answering the question "Could you outrun a Tyrannosaurus Rex?" Additional activities include learning more about how fast a Tyrannosaurus Rex runs and comparing this data to class speeds; using percent change to learn more about how stride length adapts with speed; and creating a proportional model of our class dino.

A **theropod** is a (typically carnivorous), bipedal dinosaur that has three toes and claws. A common example of a theropod is a Tyrannosaurus Rex. The measurements for foot length and stride length of the theropod prints used in the activity, as well as the theropod print image in the appendix, are from trackways found in northeastern British Columbia, Canada (MeCrea et al. 2014). The measurement used for foot length, 58 cm, is approximated from the actual length 57.93 cm.

Prerequisite Knowledge

To be successful in this activity, students should be able to use a meter stick.

Statistical Questions

One goal of this activity is for students to work with statistical questions by gathering and analyzing data in a scientific context. The main activity "A Day in the Life of a Paleontologist" focuses on three statistical questions:

1. What is the average ratio of hip height to foot length for our class?
2. How much does relative stride length vary while walking?
3. How much does relative stride length vary while running?

These are certainly not the only statistical questions that may arise for students as they consider the tracks they encounter in the classroom. If time permits, have students come up with their own statistical questions, gather data, and analyze their findings!

Scheduling and Planning

The main activity is designed to take a total of two classes, 45 minutes each, over two days. During the first day students will be introduced to the statistical questions and complete data collection. During the second day, students will analyze class data and draw conclusions to answer the question: “Could you outrun a Tyrannosaurus Rex?”

Number of Days & Guiding Questions	Content Focus	Type of activity	Relevant Handouts
2 Days “What is the hip height of a Tyrannosaurus Rex? “Could you outrun a Tyrannosaurus Rex?”	Ratios Statistical Questions and Analysis Boxplots	STEM Movement	Main Activity (A Day in the Life of a Paleontologist) (optional) Student Handout: Homework

Below is a table designed to guide modifications to the materials to fit alternative timelines. Notice that the guiding questions and content focus vary depending on the number of days available. The unifying mathematical content that is addressed is gathering data, analyzing data, and answering statistical questions in the context of paleontology.

Number of Days & Guiding Questions	Content Focus	Type of activity	Relevant Handouts
1 Day (Limited Time) “How tall is a Tyrannosaurus Rex?”	Ratios Proportions Statistical Questions and Analysis	STEM Art Movement	One-day Modified Activity: How tall is a Tyrannosaurus Rex? Followed by Additional Activity 3: Modeling our class dino
3 Days (Extension) “Could you outrun a Tyrannosaurus Rex?” “How much does stride length change as speed changes?”	Ratios Statistical Questions and Analysis Boxplots Percent Change	STEM Movement Extension	Main Activity (A Day in the Life of a Paleontologist) Followed by Additional Activity 2: Changing stride length

Goals

The main activity works best as a two-day activity and is appropriate for a 6th grade class learning about statistical questions and boxplots. The activity will review multiple topics that are covered throughout a 6th grade year including decimals, ratios, and, if using the extension, percent change. On day one students will be introduced to the statistical questions that will guide their inquiry, gather personal and class data, and work with ratios in the context of paleontology.

Students are up and moving throughout the first day as they explore their own bodies and compare their proportions and movements to that of a theropod. The common core standards that are addressed during day one include:

CCSS.MATH.CONTENT.6.RP.A.1
Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.

CCSS.MATH.CONTENT.6.RP.A.2
Understand the concept of a unit rate a/b associated with a ratio a:b with b not equal to 0, and use rate language in the context of a ratio relationship.

CCSS.MATH.CONTENT.6.SP.B.5.C
Giving quantitative measure of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.

During day two of the main activity, students will create and analyze box plots, and construct viable arguments answering the question “Could you outrun a Tyrannosaurus Rex?” The common core standards that are addressed during day two include:

CCSS.MATH.PRACTICE. MP2
Reason abstractly and quantitatively.

CCSS.MATH.PRACTICE. MP3
Construct viable arguments and critique the reasoning of others.

CCSS.MATH.CONTENT.6.SP.B.4
Display numerical data in plots on a number line, including dot plots, histograms, and box plots.

CCSS.MATH.CONTENT.6.SP.B.5.C

Giving quantitative measure of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.

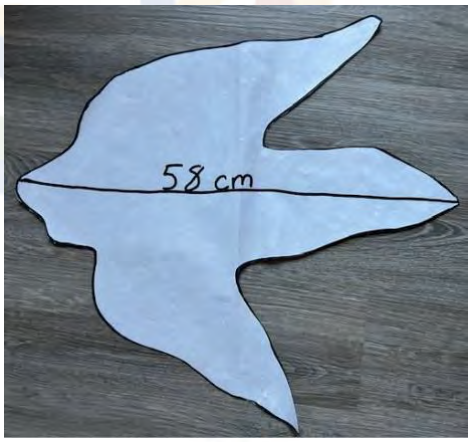
Note: If you only have one class period available, focus exclusively on the first statistical question "What is the average ratio of hip height to foot length for our class?" following One-day Modified Activity: How tall is a Tyrannosaurus Rex? Then, use the second part of class to create proportional models of the class dino using Additional Activity 3: Modeling our class dino. The goal of the one-day modification is exclusively on ratios and proportions.

Materials

- Large sheet of paper such as bulletin board paper, butcher paper, or 3 Post-it poster papers (25 in X 30 in)
- Masking tape
- Meter sticks or measuring tape
- Printed Worksheet (See Student Handout: Data Collection)
- Printed Homework (See Student Handout: Homework)
- An open space for students to walk and run at least 18 meters in length

Preparation

1. There are two options presented below for laying a trackway in the classroom, both with advantages and disadvantages.
    a. **Option 1: Using Post-it poster paper.**
        i. Draw and cut out at least 3 (i.e. left, right, left) theropod footprints, one on each Post-it poster paper that are 58 cm in length from the heel to the middle toe. Using the image in the Appendix, either project the image onto a poster paper using a classroom projector and trace the image or freehand the shape. It is helpful to label the foot length for easy reference during class, but, if time permits, you may wish to have students measure this length themselves as part of the activity.

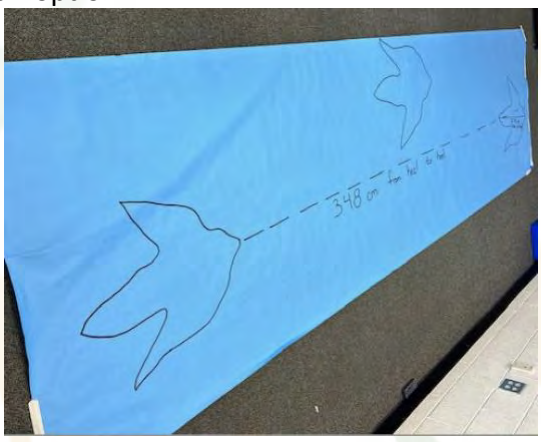


ii. Tape the footprints to your classroom floor so that the distance from the heel of the first footprint to the heel of the second footprint is approximately 174 cm and the distance from the heel of the first footprint to the heel of the third footprint is 348 cm. Label the stride length (348 cm). Notice that stride length is the distance from the heel of one foot to the heel of the next step with the same foot (i.e. from the left heel to the heel of the next step of the left foot). If you would like students to measure this length themselves this is also an option.

b. **Option 2: Using bulletin board paper or butcher paper.**

i. To draw the 3 theropod footprints, use the image in the Appendix. Either project the image onto the bulletin board paper as needed and trace the image or freehand the shape. The length of each footprint from heel to middle toe is 58 cm. Space the footprints out so that the distance from the heel of the first footprint to the heel of the second footprint is approximately 174 cm and the distance from the heel of the first footprint to the heel of the third footprint is 348 cm.

ii. Label the foot length (58 cm from heel to toe) and stride length (348 cm) as shown below. Notice that stride length is the distance from the heel of one foot to the heel of the next step with the same foot (i.e. from the left heel to the heel of the next step of the left foot). If you would like students to measure the foot length and stride length themselves this is also an option.



2. Find a place for students to walk/run (i.e. hallway, classroom, gym, or outside). Mark the starting line with tape, measure at least 18 meters from the starting line, and mark the finish line with tape. Record the total distance in centimeters for future reference.
3. Gather enough meter sticks or measuring tape for each pair of students and print enough worksheets and homework sheets for every individual student.

Overview

By the end of this two-day activity, students will answer the overarching question "Could you outrun a Tyrannosaurus Rex?" To answer this, students will explore the following statistical questions along the way:

1. What is the average ratio of hip height to foot length for our class?
2. How much does relative stride length vary while walking?
3. How much does relative stride length vary while running?

While studying trackways of dinosaurs, paleontologists ask the same three questions to grasp the nuances of what dinosaurs looked like and how dinosaurs moved through an area. Finding the average ratio of hip height to foot length and stride length variation across several data points allows paleontologists to better interpret their individual data points in comparison with other previously studied trackways.

Outline

Day One – Data Collection

Time: 40 – 50 minutes

Lay out the dinosaur trackway on the classroom floor and write the overarching question "Could you outrun a Tyrannosaurus Rex?" on the board before students walk in.

(5 minutes) Opening class discussion – Introduce the trackways (set of footprints) and ground the activity in paleontology. Possible discussion prompts with common student responses can be found below.

Over the next two days we will be exploring the question "Could you outrun a Tyrannosaurus Rex?" To answer this question, we will first need to learn more about ourselves and about dinosaurs. The trackway that we see here today is a replication of a Tyrannosaurus Rex trackway found in northeastern British Columbia, Canada by paleontologists (MeCrea et al. 2014).

1. Prompt: What do you know about paleontologists?
    - Possible student responses:
        - They study dinosaurs.
        - They look at fossils.

- They learn about animal characteristics.

2. Prompt: What information can paleontologists study from footprints or trackways?
   - Possible student responses:
     - What animal it is.
     - What the animal ate.
     - How big the animal is.
     - How fast the animal is moving.

3. Prompt: Determining how fast an animal is moving is quite the task! What are factors that influence how fast a person or animal is moving?
   - Possible student responses:
     - The leg height -> hip height
     - Frequency in stride
     - Stride length
     - What they ate
     - Where they were going

To gain a better understanding of how fast a dinosaur is moving, paleontologists study how big or tall the dinosaur is and how long their stride length is. (If the students are beginning to form the connections between stride length and hip height through the prompts, it may be nice to strengthen those connections here. Otherwise, it will become clearer through exploration.)

We are going to begin today with exploring height. Notice it is rare that paleontologists have the luxury to see and measure the full skeletal structure of a dinosaur. In many cases, they only have trackways like we see before us. Because of this, paleontologists use data that has been collected from several sites to understand the average ratio of hip height to foot length for dinosaurs. Then, they use this ratio to estimate the hip height of a dinosaur given only a footprint. Before we determine the height of our classroom dino, we are first going to follow the paleontologists research and gather data about ourselves.

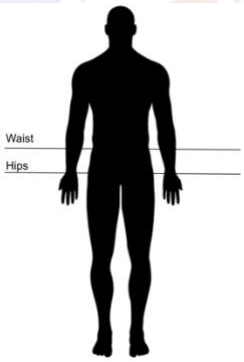
Putting on our paleontologists hat, our first statistical question is: “What is the average ratio of hip length to foot length for our class?” What makes this a statistical question?

Hand out Student Handout: Data Collection and direct students’ attention to the first page. Before handing out meter sticks, explain that students will work in pairs to measure foot length and hip height. Briefly demonstrate how to take these measurements. Direct students to write down the measurements in centimeters in the table under question three (Student Handout: Data Collection) and calculate the decimal approximation in the third column. Once they have the table completed, direct students to write the decimal approximation from the third column on the board.

Hand out meter sticks and demonstrate, for a second time, how to measure foot length from heel to toe by placing the meter stick on the ground and lining up your heel to the edge of the meter stick.

(2 minutes) Students lay the meter stick on the ground and measure their foot length in centimeters, recording their data in their table on the Student Handout: Data Collection.

(1 minute) Demonstrate how to find your hip. Most individuals will misidentify their waist as their hips, so start by putting your hands on your waist and guide students to find their hips. Using only your upper body to lean from side to side you can feel your waist moving. Since we want our hips, we should move our hands down a little bit. You know you found them when you can feel your body moving if you keep your upper body still and move your hips from side to side.



(2 minutes) In partners, students measure each other's hip height in centimeters and record their answers on their own worksheet. As one partner stands with their hands on their hips, the other measures from the floor up to the bottom of their palm. While the students are working with their partners, create a table on the board for students to record their decimal approximations from column three.

(2 minutes) Students individually calculate their ratio of hip height to foot length, recording their answer on their own table in column three and on the board.

(10-15 minutes) As students write their calculations on the board, direct students' attention to the second page of Student Handout: Data Collection. Students should note the total number of students in the class (including themselves) and record the class data in the table. Once students gather class data, they will calculate the average ratio of hip height to foot length for the class, answering the first statistical question.

Part One: Exploring Height ends with relating the class data with the dino data. Direct students' attention to the third page of Student Handout: Data Collection and calculate the hip height of the Tyrannosaur that entered the classroom. The ratio of hip height to foot length for a Tyrannosaurus Rex is four. To find the hip height students will take the foot length and multiply by four.

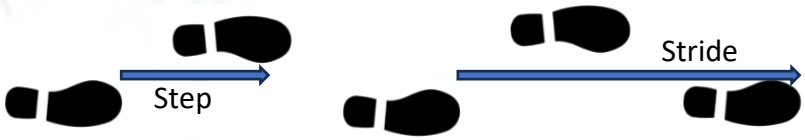
The hip height is 232 centimeters! Stacking meter sticks end to end perpendicular to the floor gives a surprising visual for students to get an idea of the enormity of the Tyrannosaur.

(4 minutes) At this point we have found the hip height of our class dino but remember that our overall goal is to see if we can outrun this dino! So we will need to focus in on movement. We

now turn our attention to our next set of statistical questions: “How much does relative stride length vary while walking?” and “How much does relative stride length vary while running?”

Since paleontologists cannot measure the speed of extinct animals, they use relative stride length to study how dinosaurs moved and variations in stride length to understand how dinosaurs to move in relation to each other. We will use box plots to analyze how our relative stride length varies, and we will see that our calculations that we just found for hip height are necessary to answering these questions. In a moment, I will demonstrate stride length. As I do, consider how hip height changes the length of a stride.

Start with a discussion on approximating stride length. Demonstrate the difference between a step (moving from your left to right foot) vs. a stride (moving from your left foot to your right foot and back to your left foot). Paleontologists use stride as a measure because of potential asymmetry of the body.



(3 minutes) Direct students’ attention to Part Two: Exploring Stride Length on Student Handout: Data Collection. Share the total distance that you marked out in centimeters and have students record under problem one of Part Two: Exploring Stride Length on Student Handout: Data Collection. Then, transition to pre-determined spot for walking and running.

(10 minutes) Students will walk and then run between the start line and finish line counting their steps, recording their data, and calculating their relative stride.

Following steps 2-6, line up students so they are standing shoulder to shoulder on the start line. Instruct student to walk naturally from the start line to the finish line and count the number of steps that they are taking.

Once the have reached the finish line, they should record their number of steps in the table below step six on Student Handout: Data Collection. Students will then calculate the number of strides (number of steps divided by 2) and estimate their stride length by dividing the number of steps by the total distance walked in centimeters. Finally, they will calculate the relative stride length by dividing stride length by hip height. Students should repeat steps 1-5 on Student Handout: Data Collection, while running.

A note on students with physical limitations: Students with any type of forward movement can participate in this activity by considering walking as a slower, natural movement forward and running as a faster movement forward. For example, if a student uses a wheelchair, they may

count their “number of steps” as being the number of grasps on the hand-rims while moving slowly versus quickly.

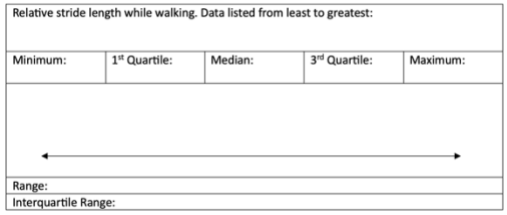
(3-6 minutes) Return to the classroom and record student data from relative stride length while walking and running on the board. Take a picture or record the data for day two.

Hand out Student Handout: Homework to be completed for homework. There is one calculation question and two reflective questions on the homework. The reflective questions ask the students to consider if they believe they could outrun a Tyrannosaurus Rex and begin to consider the limitations of the data that they are collecting.

Day Two – Data Analysis

Time: 35 – 45 minutes

(5 minutes) Start with the class data from the previous class displayed and have an opening class discussion. Students should have out Student Handout: Data Collection and Student Handout: Homework. Remind the class that they collected individual data and analyzed class data about hip height and relative stride length in the previous class. Paleontologists use these measurements to study how dinosaurs move through an area. During the opening discussion inquire about student predictions of the question "Can you outrun a Tyrannosaurs Rex?", which is the first reflection question students answered on Student Handout: Homework.



(5 minutes) On Student Handout: Data Collection students should fill in row one of the table labeled "Relative stride length while walking. Data listed from least to greatest:" using the class data from the previous day. (Table pictured to the left.)

(10-15 minutes) As a class, create the relative walking stride length boxplot together by first identifying the minimum, maximum, median, and 1st and 3rd quartile and writing in the calculations in the corresponding box in row two on the
. (Table pictured above.)

Once all data points are identified begin to create a boxplot on the number line using the line provided in the third row. Finally calculate the "Range" (row four) and "Interquartile Range"(row five).

Take a moment to step back and analyze the boxplot together with the class. What are you noticing? What are you wondering? What might the next boxplot look like? (Notice the boxplot for relative stride length while walking will most likely be more uniform with a small interquartile range since students will generally walk at a similar pace and calculate a similar relative stride length. In comparison, the boxplot for relative stride length while running will more likely have a larger interquartile range since students interpret "running" in a variety of ways.)

(10 – 15 minutes) Students work in pairs to create the relative running stride length boxplot and answer the remaining reflection questions on the Student Handout: Data Collection. Notice that question four and five is asking students to interpret the box plot and to provide an argument for how their individual data points compare to the data of the class. In the last section "Dino Data," students are asked to calculate the relative stride length of the class dino and return to the reflection question that they answered for homework. At this point, the students have learned more about how their relative stride length compares to others and to the class dino which gives them more knowledge to be able to answer the question "Could you outrun a Tyrannosaurus Rex?"

(5 minutes) Closing Discussion – Possible prompts include: What are we noticing from the boxplots and what does that information tell us? Could you outrun a dinosaur? What other information might we like to know? What is the limitation of only knowing relative stride length? (Notice that the data collected is somewhat limited because relative stride length will only signal if an animal is walking, trotting, or running; and does not signal *how fast* an animal is moving. The third question of the homework asks the students to begin to consider these limitations.)

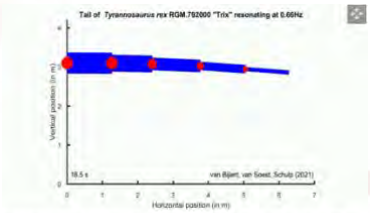
Most likely, students are interested in knowing about speed! As there is no way for Paleontologists to study extinct animals running in real time, they have devised and used the following formula[1] to approximate speed knowing only the hip height in meters and relative stride length in meters.

$$\sqrt{\frac{stride\ length}{2.3 \cdot (hip\ height)}}^{32.67 \cdot (hip\ height)}$$

Using this formula, the approximated speed of the Tyrannosaurus Rex in the classroom is 2.39 meters per second (5.33 miles per hour). If time permits, you may be interested in calculating the approximated speeds for all students. Instructions on how to do so can be found in Additional Activity 1: Let's talk speed!

(Time permitting) As an addition to the closing discussion complete the wrap-up discussion and journal prompt from Additional Activity 1: Let's talk speed! (copied below for reference).

(5 min) Wrap-up discussion by sharing research. There is newer research that shows that a Tyrannosaurus Rex moves at an even slower pace. In the following link you can see an animation of the tail movement and a gif of a Tyrannosaurus Rex walking with tail movement: https://www.livescience.com/t-rex-slow-walker-tail.html. Look for the image to the right in the article. Alternatively, watch this recap video https://cdn.jwplayer.com/previews/nkipp5lu approximately 2 min.



T. rex tail biomechanical model. (Image credit: Pasha A. van Bijlert, A. J. 'Knoek' van Soest, Anne S. Schulp)

(10 minutes) End with the following journal prompt: "Recall that the stride length for our classroom dinosaur is 348 cm. Use your data from 'A Day in the Life of a Paleontologist' to calculate how many stride lengths you (as an individual) need to cover 348 cm. **Could you outrun our classroom dinosaur?** Using everything that we learned about relative stride, speed, and distance covered to justify your answer."

[1] Thulborn, T. (1990). *Dinosaur tracks.* London: Chapman and Hall., pp. 290.

Student Handout: Data Collection

Name:_____

A Day in the Life of a Paleontologist

Part One: Exploring Height

Our Guiding Statistical Question: What is the average ratio of hip height to foot length for our class?

Individual Data:

1. Find a partner to work with. Have your partner measure your foot length in centimeters from your heel to your toe and record it in the table below. Return the favor and measure your partner's foot length.

2. Put your hands on your hip and have your partner measure from your palm down to the ground in centimeters. Record your answer in the table below and return the favor.

3. Calculate your **ratio of hip height to foot length.**

Foot Length (centimeters)	Hip Height (centimeters)	Ratio of hip height to foot length (decimal approximation)

4. Write your answer for the ratio of hip height to foot length on the board.

Class Data:

1. Count the number of students, including yourself, in our class. Write the total below. This is the number of data points that you are looking for.

Total Number of Students: _____

2. As your classmates share their data on the board, write down all the data points for the ratio of hip height to foot length in the table below. The number of data points should match your total number of students. Then, answer our statistical question!

Ratio of hip height to foot length (Decimal approximation)

What is the average ratio of hip height to foot length for our class?

Dino Data:

1. Researchers[2] have found that the ratio of the hip height to the foot length of a Tyrannosaur is four. What is the hip height of the Tyrannosaur that entered this classroom?

2. Sketch a picture of you standing next to the classroom Tyrannosaur!

2 Henderson, D. (2003). Footprints, Trackways, and Hip Heights of Bipedal Dinosaurs—Testing Hip Height Predictions with Computer Models . *Ichnos, 10*(2–4), 99–114. https://doi.org/10.1080/10420940390257914

Part Two: Exploring Stride Length

Our Guiding Statistical Questions:
How much does relative stride length vary while walking?
How much does relative stride length vary while running?

Individual Data:

1. Record the total distance that you are walking/ running in centimeters in the column labeled 'Total distance (centimeters)' in the table below.

2. Start at the starting line. As you **walk** to the finish line, count the number of steps you are taking. Record the number of steps in the table below.

3. Find the number of strides by dividing the number of steps by two and record your answer in the table below.

4. Estimate your stride length by dividing the total number of centimeters walked (step 1) by the number of strides (step 3). Record your answer in the table below.

5. Calculate your **relative stride length which is the ratio of your stride length to your hip height.**

6. Repeat steps 1-5, but this time running!

	Total distance (centimeters)	Number of steps	Number of strides	Stride length	Relative stride length (See step 5 above for description)
Walking					
Running					

7. Record your relative stride length while walking and relative stride length while running on the board.

Class Data:

1. Collect all the data points for relative stride length while walking in the table below. Calculate, or find, the minimum, median, maximum, 1st quartile, and 3rd quartile. Then, create a boxplot on the number line in row three. Finish by finding the range and interquartile range.

Relative stride length while walking. Data listed from least to greatest:				
Minimum:	1st Quartile:	Median:	3rd Quartile:	Maximum:
Range:				
Interquartile Range:				

2. Collect all the data points for relative stride length while running in the table below. Calculate, or find, the minimum, median, maximum, 1st quartile, and 3rd quartile. Then, create a boxplot on the number line in row three. Finish by finding the range and interquartile range.

Relative stride length while running. Data listed from least to greatest:				
Minimum:	1st Quartile:	Median:	3rd Quartile:	Maximum:
Range:				
Interquartile Range:				

3. What can you interpret from the data above?

4. If two people in the class had a race, could you use the data above to determine who would win? Why or why not?

Dino Data:

Now that we have considered the variations in relative stride length for walking and running in our class, let's calculate the relative stride length for our classroom dino.

1. If the stride length of the tracks in our classroom is 348 cm, was the dinosaur walking, trotting, or running?

Dino Hip Height	Dino Stride Length	Dino Relative Stride Length
	348 cm	

Recall that in 1984, Thulborn and Wade defined the three dinosaurian gaits by the table below which is generally still used by paleontologists to determine if a fossil is exhibiting walking, trotting/ jogging, or running patterns.[3]

Walk	Relative Stride Length < 2.0
Trot	2.1 ≤ Relative Stride Length ≤ 2.9
Run	2.9 < Relative Stride Length

2. Based on our data, and what you have learned throughout the activity, what can we say about the dinosaur's movements in comparison to our own movements? Could you outrun a Tyrannosaurus Rex?

[3] Thulborn, T. (1990). *Dinosaur tracks.* London: Chapman and Hall., pp. 259 – 260.

Student Handout: Homework

Name:_____

Could you outrun a Tyrannosaurus Rex?

1. Suppose we found a footprint on the playground the measures 23 centimeters. Use our classes' calculation for average ratio of hip height to foot length to approximate the hip height of this student.

2. In 1984, Thulborn and Wade defined the three dinosaurian gaits by the table below which is generally still used by paleontologists to determine if a fossil is exhibiting walking, trotting/ jogging, or running patterns.[4]

Walk	Relative Stride Length < 2.0
Trot	2.1 ≤ Relative Stride Length ≤ 2.9
Run	2.9 < Relative Stride Length

At the end of class, you calculated your relative stride length while walking and while running. Record your answers below.

	Relative Stride Length
Walking	
Running	

(continue to next page)

[4] Thulborn, T. (1990). *Dinosaur tracks.* London: Chapman and Hall., pp. 259 – 260.

Based on the information above, do you believe that you could outrun a Tyrannosaurus Rex? Why or why not? Justify your response.

3. Thus far we have only considered *relative stride length,* which focuses on how stride length changes from walking to running. What else would you like to know before to help you determine, with certainty, if you can outrun a Tyrannosaurs Rex?

Additional Activity 1: Let's talk speed!

Time: 30 minutes

Goals:

The goal of this additional activity is to extend the real-life context of the problem and consider the relationship between speed and relative stride length. In doing so, students gain a deeper understanding of the limitations of the data they collected from the main activity.

Materials:

Access to https://www.livescience.com/t-rex-slow-walker-tail.html (article form) or https://cdn.jwplayer.com/previews/nkipp5lu (video recap)

Optional: meter sticks or measuring tape

Preparation:

1. Create a google sheets document (or excel spreadsheet) label cell A1 as "Hip Height (centimeters)", cell B1 as "Stride Length (centimeters)", C1 as "Approximated Speed (meters/second)", and D1 as "Approximated Speed (miles/hour). In cell C2 enter the following formula[5]:

=sqrt(((B2/100)/(2.3*(A2/100)))^(10/3)*9.8*(A2/100))

Note: The formula above is assuming the data entered in column A and B is in centimeters.

And in cell D2 enter the following formula:

=C2*2.237

See the image below for an example of what your table will look like with data:

[5] Thulborn, T. (1990). *Dinosaur tracks.* London: Chapman and Hall., pp. 290.

C2 | =sqrt(((B2/100)/(2.3*(A2/100)))^(10/3)*9.8*(A2/100))

	A	B	C	D	E
1	**Hip Height (centimeters)**	**Stride Length (centimeters)**	**Approximated Speed (m/s)**	**Approximated Speed (mph)**	**Notes**
2	100	142	1.401351938	3.134824285	Example Student 1
3	100	245	3.478111111	7.780534555	Example Student 2
4	228	348	2.386573036	5.338763881	Dino Data
5					

2. Drag and drop the formula in C2 down column C and drag and drop the formula is D2 down column D.

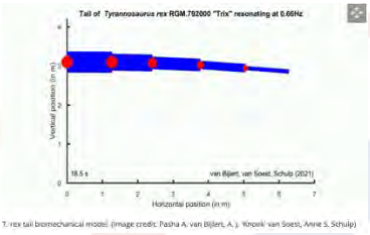
3. (Optional) Share the document with the students.

Outline:

(3 min) Open with an introduction that relates back to the main activity. We saw in our earlier activity that our stride length changes as we gain speed. Since paleontologists are unable to measure speed of animals that are extinct, they found a formula that approximates speed based on stride length and hip height. Scientists generate these formulas by running multiple experiments with animals, and humans, that they can observe, search for patterns among their data, and extrapolate a formula to be used for extinct animals. Today we are going to use that equation to approximate our own speeds and the speed of our classroom dino using only stride length and hip height.

(12 min) Using data from the previous day, enter in students' hip height and stride length to calculate approximate students' speeds. Enter the foot length and stride length for the classroom Tyrannosaurus Rex trackway into the table for comparison.

(5 min) Wrap-up discussion and sharing research. There is newer research that shows that Tyrannosaurus Rex moves at an even slower pace. In the following link you can see an animation of the tail movement and a gif of a Tyrannosaurus Rex walking with tail movement: https://www.livescience.com/t-rex-slow-walker-tail.html. Look for the image to the right in the article. Alternatively, watch this recap video https://cdn.jwplayer.com/previews/nkipp5lu approximately 2 min.



(10 minutes) End with the following journal prompt: "Recall that the stride length for our classroom dinosaur is 348 cm. Use your data from 'A Day in the Life of a Paleontologist' to calculate how many stride lengths do you need to cover 348 cm. **Could you outrun our classroom dinosaur?** Using everything that we learned about relative stride, speed, and distance covered to justify your answer."

Additional Activity 2: Changing stride length

Time: 30-45 minutes

Goals:

This is a movement-based extension activity for students to continue to discover how stride length changes with speed. The content of the activity involves percent change and covers the common core standard below:

CCSS.MATH.CONTENT.7.RP.A.3
Use proportional relationship to solve multistep ratio and percent problems.
Examples: simple interest, tax, markups and markdowns, gratuities and commissions, fees, percent increase and decrease, percent error.

Materials:

Student Handout: Changing stride length

Preparation:

Find a place for students to walk/run (i.e. hallway, classroom, gym, or outside). Mark the starting line with tape, measure at least 18 meters from the starting line, and mark the finish line with tape. Record the total distance in centimeters for future reference.

Outline:

Have students record the total distance that they are walking/ running in the first column of the table on Additional Activity 2: Changing stride length. Move to the prepared location where students should line up shoulder to shoulder on the starting line.

(20 min) Round one is walking. (Although students have already collected this data point, it is good to have them do it again as a reminder of the difference between a step and a stride.) Students count the number of steps they take from the starting line to the ending line, divide by 2 to get the number of strides, and then divide total distance by number of strides to get the approximate stride length. Students enter the data into the table on the worksheet Student Handout: Changing stride length. Repeat this process for jogging, running, and sprinting.

(23 min) Students complete the worksheet by calculating percent change and analyzing their calculations.

(2 min) Bring the class back together for a wrap-up discussion to share answers to problems 6 and 7 on Student Handout: Changing stride length.

Changing Stride Length

Today we are going to analyze how much our stride is changing as we move from walking to running.

1. Write down the pre-measured distance in the column labeled 'Distance (centimeters)' in the table below.

2. Walk the distance and record your number of steps. Divide by 2 to get your number of strides.

3. Calculate your approximated stride length. Then, calculate your approximated stride length by dividing the distance (column 1) by the number of strides (column 3).

4. Repeat this process for jogging, running, and sprinting.

	Distance (centimeters)	Number of steps	Number of strides	Approximated stride length
Walking				
Jogging				
Running				
Sprinting				

(continue to next page)

5. Calculate the percent change of your approximated stride length between the following pairs:

a) Walking and jogging

b) Jogging and running

c) Running and sprinting

d) Walking and sprinting

6. What do you notice about your calculations? What do your calculations tell you about how your speed and stride length are changing?

7. Compare your data with a neighbor. Using your data, make a prediction of who you think might win in a race. Then, test your prediction! Were you correct? Why or why not?

One-day Modified Activity: How tall is a Tyrannosaurus Rex?

Overview

By the end of this one-day activity, students will answer the overarching question “How tall is a Tyrannosaurus Rex?” To answer this, students will explore the statistical question, what is the average ratio of hip height to foot length for our class? While studying trackways of dinosaurs, paleontologists ask the same question to grasp the nuances of how tall dinosaurs were.

At the end of the activity, students will create a proportional model of themselves next to the dinosaur following Additional Activity 3: Modeling our class dino.

Outline

Time: Flexible

Prepare dinosaur trackway following the Preparation section and lay the trackway out on the classroom floor. Write on the board, “How tall is a Tyrannosaurus rex?” Set out any additional materials that students can use for Additional Activity 3: Modeling our class dino.

(5 minutes) Opening Discussion -- To answer the question “How tall is a Tyrannosaurus Rex?”, we will first need to learn more about ourselves and about dinosaurs. The trackways that we see here today are a replication of Tyrannosaurus Rex trackways found in northeastern British Columbia, Canada by paleontologists.

1. Prompt: What do you know about paleontologists?
    - Possible student responses:
        - They study dinosaurs.
        - They look at fossils.
        - They learn about animal characteristics.

2. Prompt: What information can paleontologists study from footprints or trackways?
    - Possible student responses:
        - What animal it is.
        - What the animal ate.
        - How big the animal is.
        - How fast the animal is moving.

3. Prompt: How might paleontologists study how tall a dinosaur is?
    - Possible student responses:

- By looking at how big the footprint is.
- By measuring the distance between the footprints.

It is rare that paleontologists have the luxury to see and measure the full skeletal structure of a dinosaur. In the case of the paleontologists that studied the trackways in British Columbia, they only had the trackways we see before us. Because of this, paleontologists use data that has been collected from several sites to understand the average ratio of hip height to foot length for dinosaurs.

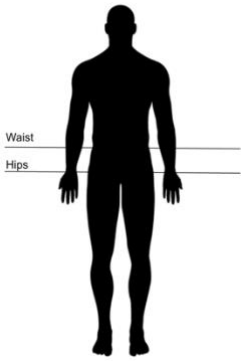
Following the same steps as the paleontologists, our guiding statistical question is: "What is the average ratio of hip length to foot length for our class?" What makes this a statistical question?

Hand out the first three pages of Student Handout: Data Collection (pages 15-17) and direct students' attention to the first page. Before handing out meter sticks, explain that students will work in partners to measure foot length and hip height. Briefly demonstrate how to take these measurements. Direct students to write down the measurements in centimeters in the table under question three (Student Handout: Data Collection). Then calculate the ratio of hip height to foot length and write the decimal approximation they obtain in the third column on the board.

Hand out meter sticks and demonstrate, for a second time, how to measure foot length from heel to toe by placing the meter stick on the ground and lining up your heel to the edge of the meter stick.

(2 minutes) Students lay the meter stick on the ground and measure their foot length in centimeters, recording their data in their table on the Student Handout: Data Collection.

(1 minute) Demonstrate how to find your hip. Most individuals will misidentify their waist as their hips, so start by putting your hands on your waist and guide students to find their hips. Using only your upper body to lean from side to side you can feel your waist moving. Since we want our hips, we should move our hands down a little bit. You know you found them when you can feel your body moving if you keep your upper body still and move your hips from side to side.



(2 minutes) In partners, students measure each other's hip height in centimeters and record their answers on their own worksheet. As one partner stands with their hands on their hips, the other measures from the floor up to the bottom of their palm.

(2 minutes) Students individually calculate their ratio of hip height to foot length, recording their answer on their own table and on the board.

(10-15 minutes) As students write their calculations on the board, direct students' attention to the second page of Student Handout: Data Collection. Students should note the total number of students in the class (including themselves) and record the class data in the table. Once students gather class data, they should calculate the average ratio of hip height to foot length for the class, answering the statistical question.

Part One: Exploring Height ends with relating the class data with the dino data. Direct students' attention to the third page of Student Handout: Data Collection and calculate the hip height of the Tyrannosaur that entered the classroom.

The hip height is 232 centimeters! Stacking meter sticks end to end perpendicular to the floor gives a surprising visual for students to get an idea of the enormity of the Tyrannosaur.

At this point you should continue to Additional Activity 3: Modeling our class dino to finish out the remainder of the class.

Additional Activity 3: Modeling our class dino

Total Time: Flexible

Goals: The goal of this additional activity is to continue to work with ratios and proportions by drawing or building a model of the class dinosaur based on research and the students' calculations.

This activity is flexible in timing and procedure. For a shorter activity provide rulers, pencils, paper, etc.

For a longer activity, provide cardboard, popsicle sticks, pipe cleaners, etc.

Materials:

- Paper
- Pencils
- Rulers

Art supplies (all optional):

- Colored papers
- Markers
- Crayons
- Cardboard or toilet paper rolls
- Popsicle sticks
- Pipe cleaners
- Glue
- Clay or Playdough

Preparation:

1. Set out the art materials.
2. Complete the guiding statistical question "What is the average ratio of hip height to foot length for our class?" following One-day Modified Activity: How tall is a Tyrannosaurus Rex?

Outline:

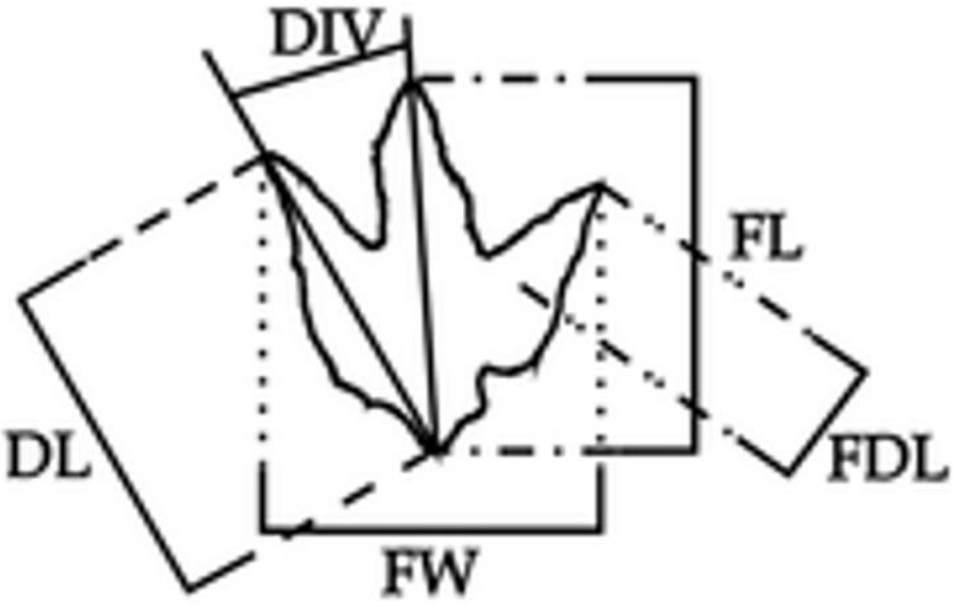
At this point, students have gathered the foot length of the class dino (theropod) and calculated the hip height of the class dino and of themselves.

(3 min) Share research behind height from head to toe. It is quite challenging to measure the "height" of a theropod for two reasons. The first reason height is challenging is because their

body length varies greatly and there are not enough fossils available to gather this data (Henderson, 2023). Of the data that is available the average body length from tip of the nose to tip of the tail is 9 meters. The second reason height is challenging is because the angle between the horizontal plane and the body axis (Thulborn, 1990) varies from 0 degrees (parallel to the ground) to 45 degrees.

Instruct students to use the rest of the activity time to draw or create a proportional model of what they think the class dino would look like standing next to them using the measurements given and measurements they calculated. Notice that there are some unknowns (which mimics what paleontologists are working with as they uncover new fossils.) End with a share out where students share their models and discuss why they chose to draw or model the dinosaur's proportions as they did.

Appendix



Note. This image is adapted from Figure 4. Methods of trackway and footprint measurements used in this study. From “A ‘terror of tyrannosaurs’: the first trackways of tyrannosaurids and evidence of gregariousness and pathology in Tyrannosauridae.” by R. T. McCrea, L. G. Buckley, J. O. Farlow, M. G. Lockley, P. J. Currie, N. A. Matthews, & S. G. Pemberton, 2014, PLoS One, 9(7), e103613. Open Access.

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